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(71) Applicant: NEC CORPORATION
Tokyo (JP)

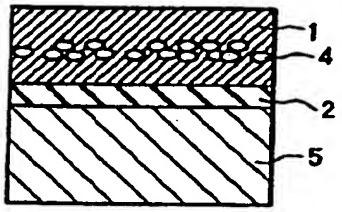
(72) Inventor: Okonogi, Kensuke
Minato-ku, Tokyo (JP)

(74) Representative:
Baronetzky, Klaus, Dipl.-Ing. et al
Patentanwälte
Dipl.-Ing. R. Splanemann, Dr. B. Reitzner, Dipl.-Ing. K. Baronetzky
Tal 13
80331 München (DE)

## (54) Laminated SOI substrate and producing method thereof

(57) An insulation film (2) is formed on a first single crystal silicon substrate (1), e.g., a hydrogen anneal substrate, an intrinsic gettering substrate and an epitaxial substrate. Hydrogen implantation is carried out from a surface of this insulation film, thereby forming a hydrogen implantation region in the first single crystal silicon substrate. Then, by carrying out a thermal treatment at 400 to 500°C, voids (4) are formed in the hydrogen implantation region, and the first single crystal silicon substrate is cleaved therefrom. Next, the surface of the insulation film and a surface of a second single crystal silicon substrate (5) are laminated and then, they are subjected to a thermal treatment at 1,000°C or higher. With this method, a bad influence on a device can be reduced and a yield can be enhanced.

FIG. 2C

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## Description

### BACKGROUND OF THE INVENTION

#### Field of the Invention

[0001] The present invention relates to a laminated SOI (Silicon On Insulator) substrate preferable for a semiconductor device and a producing method thereof, and more particularly, to a laminated SOI substrate for reducing a bad influence on a device, and a producing method thereof.

#### Description of the Related Art

[0002] As a method for producing a super thin film SOI substrate by a lamination technique, there is known a smart-cut process utilizing a phenomenon that a semiconductor substrate is cleaved by void formed by charging a large amount of hydrogen (Proceedings 1996 IEEE International SOI conference, p152). Figs.1A to 1E are sectional views sequentially showing a producing method of the SOI substrate by the conventional smart-cut process.

[0003] In the producing method of the SOI substrate according to the conventional smart-cut process, silicon film dioxide 22 which is an insulation is first formed on a single crystal silicon substrate 21 as shown in Fig.1A. A surface area of the single crystal silicon substrate 21 will be a device forming area finally. On the surface area, oxygen deposition or crystal defect region 28 such as nucleus of the oxygen deposition which is called a grown-in defect as a general term exists.

[0004] Next, as shown in Fig.1B, hydrogen ion is ion implanted from a surface of the silicon film dioxide 22 by a dose amount of about $10^{16}$ to $10^{17}$ (atoms/cm$^2$). For this reason, a hydrogen implanted region 23 is formed in the single crystal silicon substrate 21.

[0005] Then, as shown in Fig.1C, a surface of the silicon film dioxide 22 and a surface of another single crystal silicon substrate 25 are laminated at a room temperature, and are subjected to a thermal treatment at 400 to 500°C, thereby forming voids 24 in the hydrogen implanted region 23.

[0006] At that time, as shown in Fig.1D, the single crystal silicon substrate 21 is cleaved by the voids 24 formed in the hydrogen implanted region 23.

[0007] Next, a thermal treatment at about 1,000°C or higher is carried out for several hours to strongly adhere the laminated surfaces of the silicon file dioxide 22 and the single crystal silicon substrate 25. Then, a surface of the cleaved single crystal silicon substrate 21 is polished to form a mirror surface to complete the SOI substrate.

[0008] Then, the SOI substrate produced in this manner is advanced to a device forming step.

[0009] However, in the laminated SOI substrate produced by the above-described conventional method, there are problems that particles are generated in the device produced using the SOI substrate, or bonding leakage, element separation characteristic and pressure resistance of gate insulation film are deteriorated.

### SUMMARY OF THE INVENTION

[0010] It is an object of the present invention to provide a laminated SOI substrate and a producing method thereof in which a bad influence on a device can be reduced and a yield can be enhanced.

[0011] A laminated SOI substrate according to the present invention comprises a first single crystal silicon substrate and a second single crystal silicon substrate laminated on each other with an insulation film interposed therebetween. In the laminated SOI substrate, the first single crystal silicon substrate has one kind of substrate selected from a group consisting of a hydrogen anneal substrate, an intrinsic gettering substrate and an epitaxial substrate.

[0012] In the present invention, hydrogen anneal substrate, intrinsic gettering substrate or epitaxial substrate is used as the first single crystal silicon substrate on which a device is to be formed. Since crystal defects on a surface area of these substrates are extremely few, voids are suppressed from being formed on the substrate during the producing process. Therefore, it is possible to reduce a bad influence on a device.

[0013] A producing method of a laminated SOI substrate according to the present invention comprises the steps of: forming an insulation film on a surface of a first single crystal silicon substrate; forming a hydrogen implantation region in the first single crystal silicon substrate by carrying out hydrogen implantation from a surface of the insulation film; and laminating the surface of the insulation film and a surface of a second single crystal silicon substrate. In this producing method of the laminated SOI substrate, the first single crystal silicon substrate has one kind of substrate selected from a group consisting of a hydrogen anneal substrate, an intrinsic gettering substrate and an epitaxial substrate.

[0014] In the producing method of the laminated SOI substrate according to the present invention, the first single crystal silicon substrate includes a crystal defect region at a certain depth from a surface thereof.

[0015] In the present invention, since the first single crystal silicon substrate includes the crystal defect region at a certain depth from a surface thereof. If the hydrogen implantation is carried out, hydrogen is concentrated on the crystal defect region to form the voids for cleaving the substrate. That is, since voids are not formed in other regions, it is possible to reduce a bad influence on a device.

[0016] The crystal defect region may include at least one kind of crystal defect selected from a group of misfit dislocation and oxygen deposition.

[0017] Further, in the present invention, a thermal treatment at a temperature of 1,000°or higher may be

carried out after the step of laminating the surface of the insulation film and a surface of a second single crystal silicon substrate.

[0018] The misfit dislocation may be generated by forming, on a third single crystal silicon substrate, a single crystal silicon layer having a resistance higher than that of the third single crystal silicon substrate by epitaxial growth.

[0019] In order to solve the above problems, the present inventors repeated experiments, and as a result, they found that since the crystal defect region 28 (see Fig. 1A) existed irregularly in the single crystal silicon substrate 21 used in the conventional method, voids 24a were formed also in the crystal defect region 28 by the hydrogen implantation as shown in Fig.1C, and the voids 24a remained in the single crystal silicon substrate 21 which is an active layer of the SOI substrate as shown in Fig.1E and therefore, a bad influence was exerted on a device produced from this SOI substrate. That is, in the producing method of the laminated SOI substrate by this smart-cut process, it is important to control a place where the voids are formed by the hydrogen implantation. A place where the voids are formed should be a place away from a surface where the hydrogen is implanted by a distance corresponding to a range of the hydrogen. However, if there is a region around such a place where hydrogen ion such as defect is prone to concentrate, voids may be formed in such a region. Thereupon, it is necessary to control the crystallinity on the surface of the basic single crystal silicon substrate. In the present invention, a place where the voids are formed in controlled by improving the crystallinity on the surface of the basic single crystal silicon substrate.

[0020] With this feature, according to the present invention, the voids are formed in a predetermined position of the semiconductor silicon substrate, and the semiconductor silicon substrate is cleaved in the position where the voids are formed and therefore, remained voids can be reduced. Thus, a bad influence on a device can be reduced and a yield can be enhanced.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0021]

Figs.1A to 1E are sectional views sequentially showing a producing method of the SOI substrate by a conventional smart-cut process;

Figs.2A to 2E are sectional views sequentially showing a producing method of a laminated SOI substrate according to a first embodiment of the present invention; and

Figs.3A to 3E are sectional views sequentially showing a producing method of the laminated SOI substrate according to a second embodiment of the present invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0022] Preferred embodiments of the present invention will be explained concretely with reference to the accompanying drawings below.

[0023] Figs.2A to 2E are sectional views sequentially showing a producing method of a laminated SOI substrate according to a first embodiment of the present invention. In the method of the present embodiment, as a single crystal silicon substrate 1 in which hydrogen is implanted, a substrate having no grown-in defect and no oxygen deposition on a surface of the substrate and no defect region (DZ) 6 exists on surface area as shown in Fig.2A, such as a hydrogen anneal substrate, an intrinsic gettering (IG) substrate or an epitaxial substrate is used. The hydrogen anneal substrate is prepared by annealing a single crystal silicon material formed by FZ method or the like at 1,200°C for one hour in 100% hydrogen atmosphere for example. First, silicon film dioxide 2 which is an insulation material is formed on the single crystal silicon substrate 1.

[0024] Then, hydrogen ion is ion implanted from a surface of the silicon film dioxide 2 by a dose amount of about $10^{16}$ to $10^{17}$ (atoms/cm$^2$). With this operation, a hydrogen implantation region 3 is formed in only a projection range region of the single crystal silicon substrate 1.

[0025] Then, as shown in Fig.2C, a surface of the silicon film dioxide 2 and a surface of another single crystal silicon substrate 5 are laminated at a room temperature, and are subjected to a thermal treatment at 400 to 500°C, thereby forming a large number of voids 4 in the hydrogen implanted region 3 at high density.

[0026] At that time, as shown in Fig.2D, the single crystal silicon substrate 1 is cleaved by the voids 4 formed in the hydrogen implanted region 3. In the present embodiment, since there is no crystal defect region on the surface area of the single crystal silicon substrate 1, it is possible to prevent the voids from remaining in the single crystal silicon substrate 1 unlike the conventional method.

[0027] Next, a thermal treatment at about 1,000°C or higher is carried out for several hours to strongly adhere the laminated surfaces of the silicon file dioxide 2 and the single crystal silicon substrate 5. Then, as shown in Fig.2E, a surface of the cleaved single crystal silicon substrate 1 is polished to form a mirror surface to complete the SOI substrate.

[0028] The SOI substrate produced in this manner has a structure shown in Fig.2E, and voids do not exist therein. Therefore, when a device is produced from this SOI substrate, it is possible to prevent a bad influence from being exerted on the device characteristic.

[0029] Next, a method of a second embodiment of the present invention will be explained. Figs.3A to 3E are sectional views sequentially showing a producing method of a laminated SOI substrate according to the

second embodiment of the present invention. In the method of the present embodiment, as a single crystal silicon substrate 11 in which hydrogen is implanted, a substrate provided at its surface area with a misfit dislocation region 17 in which a misfit dislocation is formed. The single crystal silicon substrate 11 having the misfit dislocation region 17 can be easily formed by forming a high resistance single crystal silicon layer on a low resistance substrate by epitaxial growth, or by allowing a single crystal silicon to epitaxially grow on SiGe layer, for example. First, a silicon film dioxide 12 which is an insulation material is formed on the single crystal silicon substrate 11.

[0030] Then, as shown in Fig.3B, hydrogen ion is ion implanted from a surface of the silicon film dioxide 12 by a dose amount of about $10^{16}$ to $10^{17}$ (atoms/cm$^2$). With this operation, a hydrogen implantation region 13 is formed in only a projection range region of the single crystal silicon substrate 11 and the misfit dislocation region 17.

[0031] Then, as shown in Fig.3C, a surface of the silicon film dioxide 12 and a surface of another single crystal silicon substrate 15 are laminated at a room temperature, and are subjected to a thermal treatment at 400 to 500°C, thereby forming a large number of voids 14 in the hydrogen implanted region 13 at high density.

[0032] At that time, as shown in Fig.3D, the single crystal silicon substrate 11 is cleaved by the voids 14 formed in the hydrogen implanted region 13. In the present embodiment also, since there is no crystal defect region on the surface area of the single crystal silicon substrate 11, it is possible to prevent the voids from remaining in the single crystal silicon substrate 11 unlike the conventional method.

[0033] Next, a thermal treatment at about 1,000°C or higher is carried out for several hours to strongly adhere the laminated surfaces of the silicon file dioxide 12 and the single crystal silicon substrate 15. Then, as shown in Fig.3E, a surface of the cleaved single crystal silicon substrate 11 is polished to form a mirror surface to complete the SOI substrate.

[0034] The SOI substrate produced in this manner has a structure shown in Fig.3E, and voids do not exist therein. Therefore, as the SOI substrate produced by the method of the first embodiment, when a device is produced from this SOI substrate, it is possible to prevent a bad influence from being exerted on the device characteristic.

[0035] Although a substrate having the misfit dislocation region is used as the single crystal silicon substrate in the present embodiment, a substrate provided in its surface area with an oxygen deposition layer may be used. The substrate having the oxygen deposition layer is formed by cleansing a basic single crystal silicon substrate with hydrofluoric acid aqueous solution and they, by allowing a single crystal silicon layer to epitaxially grow on the basic single crystal silicon substrate.

## Claims

1. A laminated SOI substrate, comprising:

   a first single crystal silicon substrate (1);
   a second single crystal silicon substrate (5); and
   an insulation film (2) interposed between said first and second single crystal silicon substrates,
   characterized in that
   said first single crystal silicon substrate (1) has one kind of substrate selected from a group consisting of a hydrogen anneal substrate, an intrinsic gettering substrate and an epitaxial substrate.

2. A producing method of a laminated SOI substrate, characterized by comprising the steps of:

   forming an insulation film (2) on a surface of a first single crystal silicon substrate (1) which has one kind of substrate selected from a group consisting of a hydrogen anneal substrate, an intrinsic gettering substrate and an epitaxial substrate;
   forming a hydrogen implantation region (3) in said first single crystal silicon substrate by carrying out hydrogen implantation from a surface of said insulation film; and
   laminating said surface of said insulation film and a surface of a second single crystal silicon substrate (5).

3. A producing method of a laminated SOL substrate, characterized by comprising the steps of:

   forming an insulation film (2) on a surface of a first single crystal silicon substrate (1) which includes a crystal defect region (17) at a certain depth from a surface thereof;
   forming a hydrogen implantation region (3) in said first single crystal silicon substrate (1) by carrying out hydrogen implantation from a surface of said insulation film; and
   laminating said surface of said insulation film and a surface of a second single crystal silicon substrate (5).

4. A producing method of a laminated SOI substrate according to claim 3, characterized in that said crystal defect region (17) includes at least one kind of crystal defect selected from a group of misfit dislocation and oxygen deposition.

5. A producing method of a laminated SOI substrate according to claim 2, characterized by further comprising a step of conducting a thermal treatment at

a temperature of 1,000°C or higher, after said step of laminating said surface of said insulation film and said surface of said second single crystal silicon substrate.

6. A producing method of a laminated SOI substrate according to claim 3, characterized by further comprising a step of conducting a thermal treatment at a temperature of 1,000°C or higher, after said step of laminating said surface of said insulation film and said surface of said second single crystal silicon substrate.

7. A producing method of a laminated SOI substrate according to claim 4, characterized in that said misfit dislocation is generated by forming, on a third single crystal silicon substrate, a single crystal silicon layer having a resistance higher than that of said third single crystal silicon substrate by epitaxial growth.

FIG. 1A

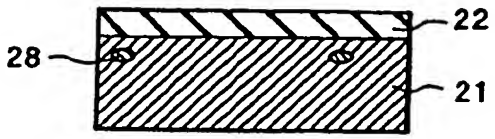



FIG. 1B

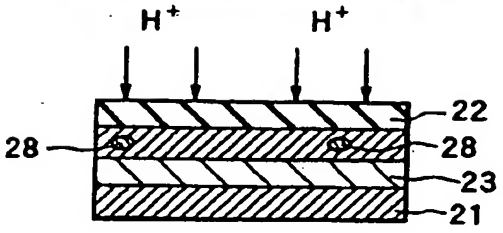



FIG. 1C

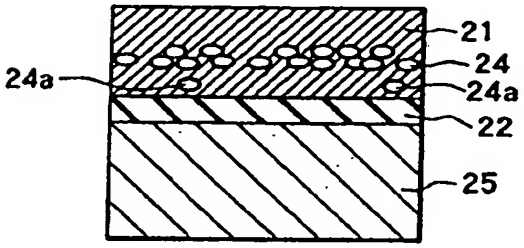



FIG. 1D

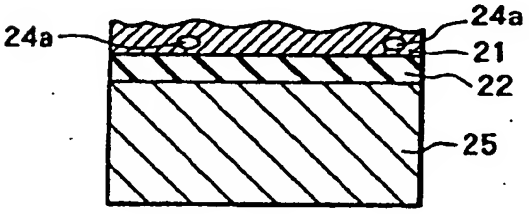



FIG. 1E

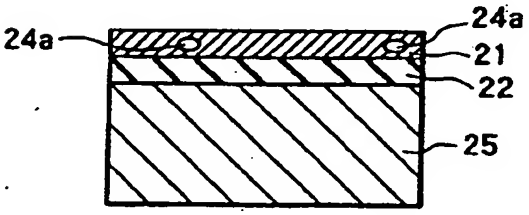


FIG. 2A

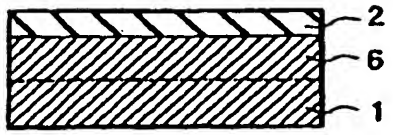



FIG. 2B

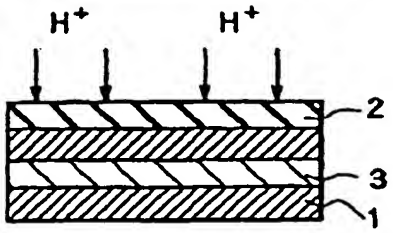



FIG. 2C

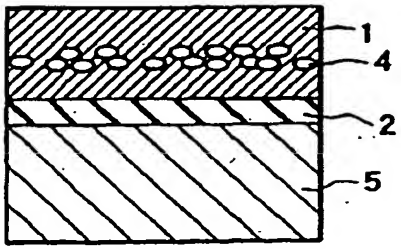



FIG. 2D

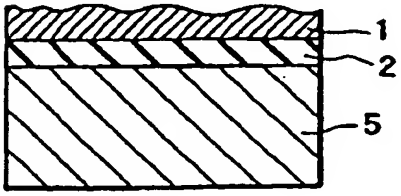



FIG. 2E

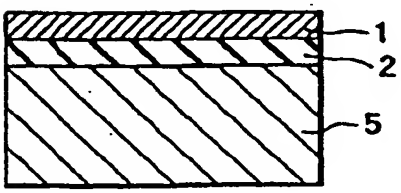


FIG. 3A

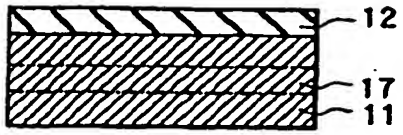



FIG. 3B

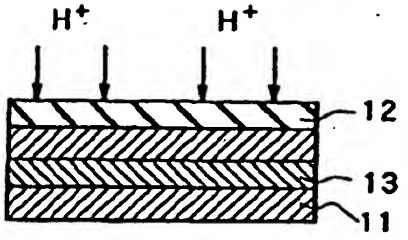



FIG. 3C

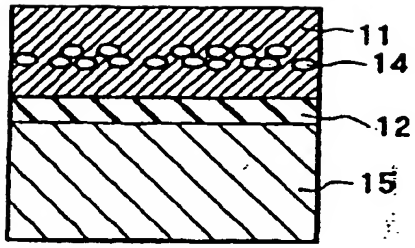



FIG. 3D

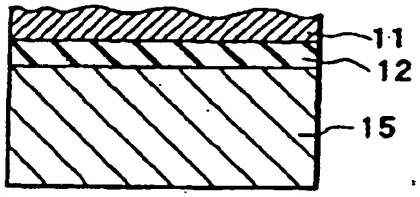
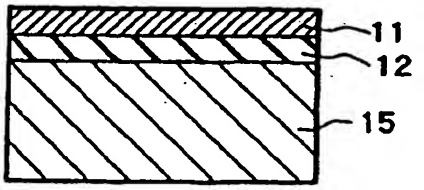



FIG. 3E



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# EUROPEAN SEARCH REPORT

Application Number
EP 98 12 1271

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The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| BERLIN | 12 February 1999 | Hamdani, F |

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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